Jurnal Teknik Sipil: Vol 24, No. 1, February 2024, 708-720
Department of Civil Engineering, University of Tanjungpura.
ISSN: 1412-3576 (Print), 2621-8429 (Online), Indonesia

Constructions of UNTAN
Jurnal Teknik Sipil
Journal homepage: https://jurnal.untan.ac.id/index.php/jtsuntan

Rainwater Harvesting Analysis for ICU Building of Dr. Agoesdjam Regional General Hospital, Ketapang

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ABSTRACT

Clean water is indispensable for public health, especially in healthcare facilities like hospitals, which require a reliable supply to support various medical and non-medical activities. dr. Agoesdjam Regional General Hospital (RGH) in Ketapang is vital in delivering healthcare services to its community. Given challenges with traditional clean water sources, rainwater harvesting (RWH) emerges as an appealing alternative in areas lacking adequate water infrastructure.
This study focuses on planning a rainwater harvesting system at dr. Agoesdjam RGH, identifying rainwater potential, designing collection and storage systems, and evaluating sustainability and effectiveness in meeting hospital water demands. The significance lies in advancing sustainable water supply systems for hospitals and guiding similar facilities toward adopting rainwater as a viable water source, enhancing healthcare service delivery and community access to clean water.

The analysis shows that the daily demand for clean water for the ICU building at Dr. Agoesdjam RGH is 2.6 m³/day, translating to 78 m³/month based on standard guidelines. Rainfall intensity calculations (120 mm/hour) indicate a need for roof area adjustments to optimize rainwater capture. Specific gutter dimensions (8-inch horizontal, 4-inch vertical) are determined for efficient water flow. A ground tank with a volume of 135 m³ is planned to ensure adequate water storage. This research underscores the critical role of rainwater harvesting in hospital water supply management, providing insights for effective implementation and contributing to sustainable healthcare infrastructure development.

Keyword: Rainwater Harvesting, Ketapang, Clean Water

ARTICLE INFO

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Citation:

Kisnadharma, A.G.; Winardi; Gunarto, D. **Rainwater Harvesting Analysis for ICU Building of Dr. Agoesdjam Regional General Hospital, Ketapang.** Journal of Civil Engineering (JTS) Vol. 24, 1. p.708-720. https://doi.org/10.26418/jts.v24i1.75858

Submitted: 15 January 2024
Accepted: 01 April 2024
Revised: 05 April 2024
Published: 07 April 2024

1. Introduction

Clean water is crucial for public health (Wuysang & Soeryamassoeka, 2021; Pratama et al., 2022). Hospitals are one such institution that requires an adequate supply of clean water to support various medical and non-medical activities (Gerber et al., 2017; Theron et al., 2022). dr. Agoesdjam Regional General Hospital (RGH), Ketapang, plays a crucial role in providing healthcare services to the community in that area.

In many areas, especially in rural or urban areas that are not fully covered by adequate clean water infrastructure, using rainwater as a source of clean water is an attractive and potential alternative to developed (Soeryaassoeka et al., 2018; Mukaromah, 2020; Wuysang & Soeryamassoeka, 2021). Rainwater harvesting (RWH) entails gathering and storing rainwater instead of letting it run. Rainwater is gathered from a surface resembling a roof and diverted towards a receptacle such as a tank, cistern, or underground reservoir, allowing it to percolate into the ground and replenish groundwater levels gradually (Campisano et al., 2017; de Sá Silva, 2022). However, in the context of hospitals, planning clean water supply systems that integrate rainwater utilization still needs more attention (Pokhrel et al., 2022). Indeed, through rainwater, hospitals can diminish their reliance on traditional sources of clean water, such as potable or tap water, which are frequently restricted or challenging to obtain (Raimondi et al., 2022).

Therefore, this study aims to plan a water supply system in dr. Agoesdjam Regional General Hospital, Ketapang, utilizes rainwater harvesting as one of its main components. In this context, the planning includes identifying rainwater harvesting potential in the hospital area, designing the rainwater collection and storage system, and evaluating the sustainability and effectiveness of the system in meeting the hospital's clean water demands.

The urgency and significance of this study lie in its potential to advance the creation of a sustainable and adequate clean water supply system for hospitals. Moreover, it can guide other healthcare facilities to consider rainwater as a viable alternative water source. Consequently, this research has the potential to enhance the accessibility of clean water in hospitals and bolster endeavors to deliver high-quality healthcare services to the community.

2. Materials and Methods

2.1. Study Area

This research was conducted at Dr. Agoesdjam Regional General Hospital at Jl. MayJend D.I. Panjaitan number 51, Sampit Village, Delta Pawan District, Ketapang Regency. Dr. Agoesdjam Hospital has been utilized for hospital operational activities that provide comprehensive health services to the community, especially the community in Ketapang Regency.

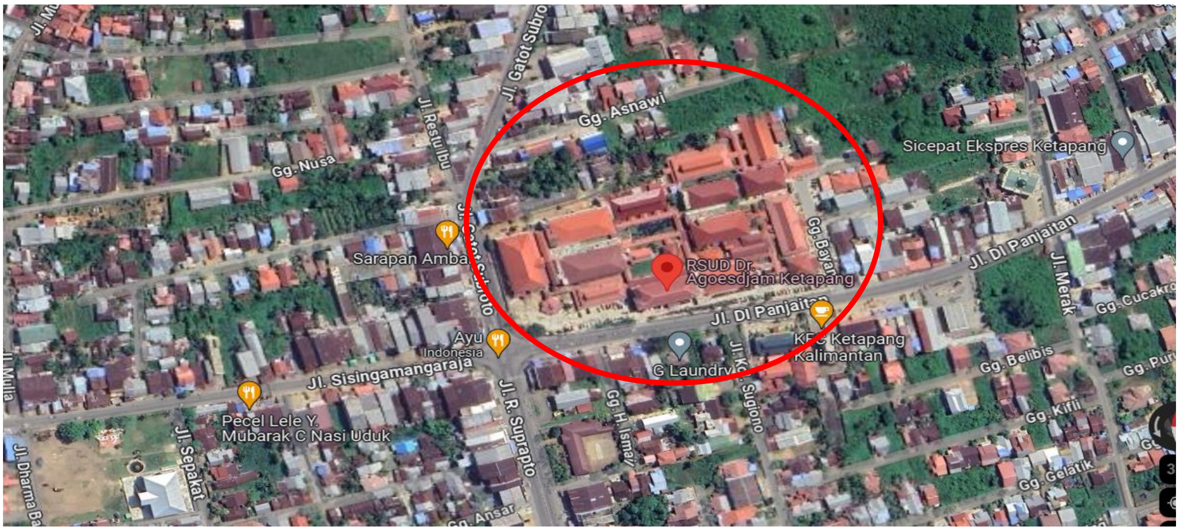

Fig 1. Study Area

dr. Agoesdjam Regional General Hospital (RGH) is a government-owned hospital established with funding from the State Budget (APBN) and assistance from the Asian Development Bank (ADB). dr. Agoesdjam RGH has been operating since 1984. To improve service facilities, hospital development and expansion are conducted. With the growth and expansion of the hospital, more water supply is required—currently, the clean water supply for dr. Agoesdjam RGH is obtained from the regional public water company, Tirta Pawan, but the clean water supply still often experiences quality and quantity issues. Since hospitals are public facilities that consume a large amount of clean water, ideally, they should have alternative sources of clean water supply that can be used to meet their clean water demands.

To meet dr. Agoesdjam RGH's clean water demands, planning is being carried out to harvest rainwater using a gutter system, a network resembling pipes primarily designed to channel rainwater from the roof to desired locations. In this study, the rainwater harvesting system utilizes the area around the Intensive Care Unit (ICU) building precisely by utilizing the roof of the ICU building, which is then directed into water storage tanks around the ICU building—the roof of the ICU building at dr. Agoesdjam Ketapang Regional General Hospital, used as a rainwater catchment area, includes all sides of the roof to maximize rainwater harvesting. The shape of the ICU building's roof can be seen in Figure 2. Since the construction of the new building placement, dr. Agoesdjam Regional General Hospital has an area of 40.4 hectares, with a building area of 28,504 square meters.

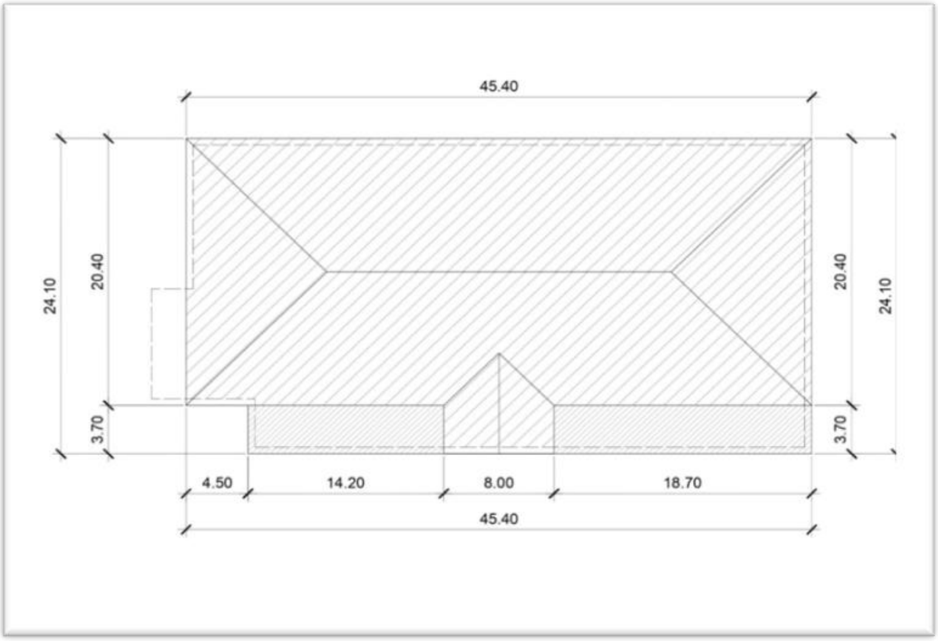

Fig 2. The shape of the ICU Hospital Building's roof

dr. Agoesdjam RGH has a shield-shaped roof. According to Sudarmadji (2014), the shield-shaped roof is a development from the saddle roof, which consists of sloping planes on all sides, formed by two triangular planes and one trapezoidal plane. The slope angle of the roof is not always the same, depending on the type of roofing material used.

Table 1. Roof Shape and Slope Angle

No	Roof shape	Roof slope angle
1	Standard roof	30^{o} - 40^{o}
2	Tower roof	75^{o}
3	Gable roof	30^{o} - 40^{o}

2.2. Data

The data used in this study consists of primary and secondary data. The primary data includes the possible rainwater catchment areas at dr. Agoesdjam RGH, the hospital building's existing conditions, and the clean water piping system. These data are used to analyze the entire hospital population's clean water demands and rainwater storage capacity, serving as inputs in designing suitable systems for the existing hospital building. Meanwhile, the secondary data includes the length, width, and area of the rainwater catchment, rainfall data for Ketapang Regency, standard clean water requirements per bed per day, and hospital building floor plans.

2.3. Analysis Method

2.3.1. Analysis of Clean Water Demands

Rainwater requirement refers to the volume of rainwater used by employees and visitors for daily purposes over one month (Suwarno et al., 2021). The comparison of the number of employees and visitors with the clean water requirement is calculated using the following equation:

$B = D \times P \times 30$ ....(1)

B : Total monthly water requirement (m^3)
D : Standard water requirement (m^3/bed) (SNI-03-7065-2005)
P : Number of Users (individuals)

2.3.2. Analysis of Rainwater Catchment Area

Calculating the roof area is necessary to determine the extent of the catchment area and rainwater supply that will be utilized. To calculate the required roof area to determine the extent of the catchment area and rainwater supply, follow these steps:

a. Measure Roof Area: Measure the length and width of the roof to obtain the area in square meters (m^2).

b. Determine Water Catchment Efficiency: Water catchment efficiency is the percentage of rainwater that falls on the roof and is successfully captured. It can vary depending on roof slope, material, and weather conditions. For calculation purposes, assume the water catchment efficiency to be approximately 80% to 90%.

c. Calculate Captured Water Volume: The volume of captured water can be calculated using the formula:

   Water Volume = Roof Area × Rainfall × Water Catchment Efficiency..............................(2)

   Roof Area is the roof area in the same unit as rainfall. Rainfall is the rainfall that occurs within a specific period, usually measured in millimeters (mm). Water Catchment Efficiency is the percentage of rainwater successfully captured by the roof.

The equation used to calculate the roof area in Dr. Agoesdjam RGH's method is as follows:

$L_s = Y.X. \dfrac{x}{cos\propto}$ ....(2)

L_s : Surface area of inclined side (m^2)
Y : Length of the side (m)
X : Width of the side projection (m)
α : Roof slope angle

2.3.3. Analysis of rainfall

a. Rainwater Quality

In this study, the quality of rainwater is analyzed by comparing the rainwater quality data obtained from the Laboratory of the Regional Drinking Water Company Tirta Pawan with the clean water quality standard according to the Regulation of the Minister of Health of the Republic of Indonesia Number 32 Year 2017.

b. Designed Rainfall

Designed rainfall estimates the amount expected to occur in a watershed area. In this study, the analysis of planned rainfall is conducted using the Gumbel Method. This approach is commonly employed to analyze surface runoff and flood frequency in a Watershed (DAS) (Chikabvumbwa et al., 2017; Jarwinda, 2021; Ruhiat, 2022). The data generated using this method consists of maximum rainfall data over one year. Maximum rainfall is crucial information as it is one of the factors that can cause maximum flooding in a watershed. Maximum rainfall data can also be used to plan river flood control structures (Da Silva et al., 2018). Annual rainfall data also serves beneficially in designing dam structures, irrigation networks, drainage channels, and so forth (Sen, 2020). The following is the formula for calculating planned rainfall analysis using the Gumbel distribution method (Chikabvumbwa et al., 2017).

$X_t = X_r + (K.S_x)$...(3)

X_t : Annual design rainfall (mm)
X_r : Average maximum rainfall
K = $\frac{Y_t - Y_n}{S_n}$ ....(4)

K : Frequency Factor
Yt : Reduced variated
Y_n : Average reduced variated
S_r : Reduced standard deviation
S_x = $Square\sqrt{\frac{\sum_{i=1}^{n}(X_i - X_r)^2}{n-1}}$...(5)

S_x : Standard deviation
X_i : Average rainfall
X_r : Mean maximum rainfall
n : Total data

c. Rainfall intensity

The intensity of rainfall refers to the amount of rainwater per unit of time. Generally, shorter periods of rain result in higher intensity, while longer intervals between rain events correspond to greater intensity. Analyzing rainfall intensity can be conducted using historical rainfall data (Hidayati et al., 2023). In this study, rainfall intensity is analyzed using the Monobe method, the equation of which is as follows:

I = $\frac{R_{24}}{24}\left(\frac{24}{t}\right)^{2/3}$ ....(6)

I : Rainfall intensity (mm/hour)
R_{24} : Maximum daily rainfall (mm)
t : Duration of rainfall (hours)

d. Reliable rainfall

Reliable rainfall refers to rainfall that can be consistently and accurately predicted or forecasted over a certain period and with a certain confidence level.

In this study, reliable rainfall is analyzed first using the Basic Year Method to obtain dependable flow. This method analyzes the data of maximum rainfall amounts sorted from highest to lowest values and determines their probabilities. From various probabilities, rainfall data with an 80% reliability level, or the closest to it, will be selected using the Weibull formula.

P = $\frac{m}{n=1}$ x 100%...(7)

P : Probability.
m : The sequence number of data from the sorted series.
n : The number of data.

e. Analysis of Rainwater supply

The rainwater supply is required to determine the volume of rainwater that can be captured (Sample & Liu, 2014). The following is the general equation used in the calculation:

$$V = R.A.C \quad (8)$$

V : Captured water volume (m^3)
R : Rainfall (mm/month)
A : Catchment area (m^2)
C : Runoff coefficient, with a value taken as 0.9

f. Planning of Drainage System

The gutter used is made of polyvinyl chloride (PVC). This planning includes the calculation of dimensions for both horizontal and vertical gutters leading to the ground water tank. Calculating dimensions for horizontal and vertical gutters requires data on the planned roof area and rainfall intensity based on a 5-year rainfall recurrence period. The calculation of dimensions for the half-circle horizontal gutter and vertical and horizontal gutters refers to the Indonesian National Standard (SNI) 03-7065-2005 on Plumbing System Planning Procedures. Below are the equations used to determine the dimensions of the gutters used.

The analysis of rainwater discharge flowing on the roof and channeled through the gutter is determined using the following equation:

$$Q=0{,}278 \times C \times I \times A \times 10^{-6} \quad (9)$$

Q : Rainwater discharge (m^3/second)
C : Runoff coefficient, with a value taken as 0.9
I : Rainfall intensity (mm/hour)
A : Catchment area (m^2)

Next, an analysis of the water depth in the channel is conducted using the equation:

$$Y_n = \left(\frac{q \; x \; n}{1{,}26\sqrt{s}}\right)^{\frac{3}{8}} \quad (10)$$

Y_n : Water depth in the channel
q : Rainwater discharge (m^3/second)
n : Manning coefficient
s : Channel slope (mm/%)

In the gutter, the flow discharge (Qs) is calculated using the equation;

$$Qs = V \; X \; A \quad (11)$$

Q : Flow discharge (m^3/second)
V : Flow velocity (m/s)
A : The cross-sectional area of the gutter

g. First flush diverter planning

The First Flush Diverter is essential for reducing debris entry during the initial rainfall, which often carries numerous contaminants. It diverts the first flush runoff from rain and prevents it from entering the rainwater harvesting tank to maintain the quality of rainwater. The sizing of the vertical pipe as the first flush diverter follows the guidelines outlined in the Indonesian National Standard (SNI) 8153-2005.

h. Rainwater harvesting tank volume planning

The planning of tank volume should be balanced between water supply and demand. The calculation of tank volume can be done using the equation:

$$V_{Supply} = V_{Demand} \quad (12)$$

$$V_{Tank} = \frac{V_{\text{Rainy Season Supply}}}{n} \quad (13)$$

V_{Supply} : Availability of rainwater supply (m^3)
V_{Demand} : Water demand in one month (m^3)
V_{Tank} : Ground tank volume in one month (m^3)

The shape of the tank cross-section used is rectangular, so the dimensions of the tank can be determined using the following equation:

$$V = P \times L \times T \quad (14)$$

V : Tank volume (m^3)
P : Length (m)
L : Width (m)
T Height (m)

3. Results and Discussion

3.1. Clean Water Demands

The clean water demand at dr. Agoesdjam RGH is calculated based on the number of employees and beds in the ICU building. The standard clean water requirement in this planning follows hospital building usage guidelines according to SNI-03-7065-2005 on Plumbing System Planning Procedures. According to these standards, the clean water requirement is 200 liters per bed per day and 50 liters per employee per day. In the ICU building, there are 10 beds and 12 employees. Therefore, the calculated clean water demands can be detailed as follows:

a. Clean water demand for beds:

Total beds = 10, clean water requirement per bed = 200 liters/bed/day

Total clean water demand for beds = 10 beds × 200 liters/bed/day = 2000 liters/day = 2 m^3/day.

b. Clean water demand for employees:

Total employees = 12, clean water requirement per employee = 50 liters/employee/day
Total clean water demand for employees = 12 employees × 50 liters/employee/day = 600 liters/day = 0,6 m^3/day

Therefore, the total clean water demand at Dr. Agoesdjam RGH for the ICU building is calculated as follows:
Total clean water demand = Clean water demand for beds + Clean water demand for employees = 2 m^3/day (for beds) + 0.6 m^3/day (for employees)
= 2.6 m^3/day
To calculate the monthly clean water demand:
Total clean water demand per month = 2.6 m^3/day × 30 days = 78 m^3/month

3.2. Rainwater Catchment Area

Based on Figure 2, the roof of the ICU building at dr. Agoesdjam RGH is rectangular, with a length (L) of 45.40 meters and a width (W) of 20.40 meters. In this planning, the surface area used as the rainwater harvesting catchment area is the top part of the ICU building roof.

Therefore, the roof dimensions are the length (L) and the width of the roof (W). The roof area (A) is Length (L) × Width (W) = 45.40 meters × 20.40 meters = 926.16 square meters. Thus, the total area of the roof used as the rainwater harvesting catchment area is 926.16 square meters, representing the entire roof area of the building.

3.3. Rainwater Quality

The quality of rainwater is generally influenced by the location where the rain falls (rainwater catchment area). Since water quality testing is not conducted in Ketapang, where Dr. Agoesdjam RGH is located, this study uses rainwater quality data based on analyses conducted in Pontianak City and Kubu Raya District, which are within the same province of West Kalimantan. Rainwater quality in locations within the same region is assumed to be relatively similar.

Based on the research conducted by Fadillah et al. in 2003, it is known that the pH of rainwater in the Pontianak City area is 6.65, which falls into the category of perfect pH for rainwater, tending towards neutral like surface water and therefore suitable for consumption during that month. Meanwhile, the nitrate content in the Pontianak City area for May was recorded at 2.90, which is considered good as there was no haze from forest fires, and it was the rainy season, resulting in lower nitrate levels. The sulfate content was also measured at 15.61, which also falls into the excellent category, indicating that it is still safe for consumption and does not pose a health risk.

In Kubu Raya, the findings from rainwater quality tests conducted in 2022 show that the Iron (Fe) concentration is 0.02 mg/l, and Lead (Pb) was not detected (0.0 mg/l) (Dentry et al., 2023). According to Ministry of Health Regulation No. 32 of 2017, which sets the standard quality requirements for environmental health in water used for hygiene and sanitation, the allowable limits for Iron (Fe) and Lead (Pb) are one mg/l and 0.05 mg/l, respectively. Consequently, these test results are significantly below the established water quality thresholds.

3.4. Designed Rainfall

Table 2 presents the results of the planned rainfall analysis using the Gumbel Type I Method using equations (3), (4), and (5).

Table 2. dr. Agoesdjam RGH ICU Building Designed Rainfall Analysis Result

Return Period	Xr	K	Sd	Xt
2	355.4	-0,135	67,265	346,26
5	355,4	0,9975	67,265	422,50
10	355,4	1,7479	67,265	472,97
15	355,4	2,1713	67,265	501,45
20	355,4	2,4677	67,265	521,39

X_r : Average maximum rainfall
K : Frequency Factor
Sd : Standard deviation
X_r : Average maximum rainfall

3.5. Rainfall Intensity

By utilizing equation (6) and incorporating the results of the designed rainfall analysis as the maximum rainfall (R_{24}), the rainfall intensity at the research site is obtained, as presented in Table (3).

Table 3. Results of Rainfall Intensity Analysis at the dr. Agoesdjam RGH ICU Building for Various Return Periods with Different Duration Variations

Duration (Hour)	Return Period				
	2	5	10	15	20
0,08	644	786	880	933	970
0,16	406	495	555	588	611
0,25	302	368	412	437	454
0,5	190	232	260	275	286
1	120	146	164	173	180
2	75	92	103	109	114
4	48	58	65	69	72
5	41	50	56	59	62
6	36	44	50	53	55
7	33	40	45	47	49

The results of calculating rainfall intensity in the ICU building at Dr. Agoesdjam RGH yielded 120 mm/hour, indicating a value exceeding 100 mm/hour. Based on the SNI 03-7065-2005 reference, if the rainfall intensity value exceeds 100 mm/hour, then the area value in the table must be adjusted as follows:

$$\text{New Roof Area} = \text{Original Roof Area} \times \frac{10}{Excess\ Intensity}$$

$$\text{New Roof Area} = 926 \times \frac{10}{(120-100)} = 463\ \text{m}^2.$$

This new roof area value will be used to plan the rainwater harvesting system for the ICU dr—Agoesdjam RGH building.

3.6. Reliable Rainfall

Using equation (7), the magnitude of reliable rainfall for dr. Agoesdjam RHG is obtained, with the results presented in Table 4.

Table 4. dr. Agoesdjam RHG ICU Building Reliable Rainfall

m	P(%)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	6%	361,3	287,5	440,7	454,7	342,7	320,0	240,5	203,7	244,0	401,5	437,0	422,0
2	13%	359,5	271,0	329,0	397,3	285,3	302,7	239,0	193,3	225,0	310,0	386,7	294,0
3	19%	309,3	239,3	238,7	314,7	266,5	248,0	177,0	172,0	194,5	229,5	378,7	170,5
4	25%	308,0	223,3	237,5	312,3	246,0	198,5	161,0	166,7	191,3	210,0	372,3	226,5
5	31%	272,5	209,0	224,0	273,5	219,0	193,5	157,7	158,0	173,0	168,7	369,5	342,7
6	38%	263,3	202,5	210,3	214,0	215,5	162,7	123,7	141,0	103,0	94,7	346,5	326,7
7	44%	215,5	199,7	185,0	208,0	199,7	144,7	89,5	116,3	101,0	221,7	312,5	393,0
8	50%	210,0	182,0	184,7	202,0	178,0	135,0	82,5	96,5	94,5	33,3	312,0	440,7
9	56%	204,0	238,0	197,5	265,5	209,5	253,0	174,5	141,0	246,3	179,5	284,3	274,5
10	63%	192,7	153,7	170,5	183,0	173,3	117,5	64,0	62,0	82,7	389,3	230,0	245,3
11	69%	180,5	117,5	165,7	165,0	108,5	108,7	41,0	43,0	73,5	236,7	216,0	339,3
12	75%	176,0	90,5	154,7	163,0	106,5	78,7	32,3	11,0	62,0	159,0	204,5	324,0
13	81%	137,7	28,0	99,5	140,0	97,7	51,0	25,0	11,0	19,7	186,0	181,5	247,5
14	88%	83,3	26,0	92,0	74,0	66,5	49,7	16,0	8,0	0,7	265,0	179,0	189,5
15	94%	83,0	14,0	72,0	72,0	53,0	16,5	4,0	3,7	0,0	164,5	171,0	320,0
Average		223,78	165,47	200,11	229,27	184,51	158,67	108,51	101,81	120,74	216,62	292,1	303,74
Reliable rainfall 80%		**145,33**	**40,5**	**110,53**	**144,6**	**99,43**	**56,53**	**26,47**	**11**	**28,13**	**180,6**	**186,1**	**262,8**

Table 4 shows that the highest rainfall occurred in December, amounting to 262.8 mm, while the lowest rainfall occurred in August, with only 11 mm. The high rainfall in December is attributed to the peak of the rainy season, whereas the low rainfall in August is due to the dry season. The reliable rainfall data suggests a potential water shortage during the dry months, where the low rainfall and limited harvestable water may not meet water demands.

3.7. Rainwater Supply

Rainwater supply for clean water is influenced by building roof area, rain catchment area, rainfall, and runoff coefficient. Calculating the rainwater supply is essential to determining the volume of rainwater that can be harvested. Equation (8) can be used to obtain the volume of rainwater that can be captured for each month based on the roof area data used, as presented in Table 5.

Table 5. dr. Agoesdjam RHG ICU Building Rainwater Supply

Month	**Days**	**Reliable Rainfall (mm)**	**Roof Area (m^2)**	**Rainwater Supply (m^3)**	**Water Demands (m^3)**
Jan	31	145,33	926	121,12	80,6
Feb	28	40,5	926	33,75	72,8
Mar	31	110,53	926	92,12	80,6
Apr	30	144,6	926	120,51	78
Mei	31	99,43	926	82,87	80,6
Juni	30	56,53	926	47,11	78
Juli	31	26,47	926	22,06	80,6
Agst	31	11	926	9,17	80,6
Sept	30	28,13	926	23,45	78
Okt	31	180,6	926	150,51	80,6
Nov	30	186,1	926	155,1	78
Des	31	262,8	926	219,02	80,6
Tot	**365**	**1292,03**		**1076,78**	**949,00**

The table above shows the amount of rainwater that can be captured at dr. Agoesdjam RHG's ICU building, with a roof area of 926 m^2, over one year, amounting to approximately 1076.78 or 1077 m^3.

3.8. Planning a rainwater harvesting system for the ICU at dr. Agoesdjam RGH

3.8.1. Gutter Planning

After analyzing the clean water requirements and availability, the next step is to plan a rainwater harvesting network system for the ICU building at dr. Agoesdjam RGH. The planned harvesting system involves using gutter systems connected to storage tanks.

With a roof area of 463 m2 and a planned slope of 2%, the required pipe diameter is 250 mm. The calculation of this plan's half-circle horizontal gutter size follows the SNI 03-7065-2005 standard. The half-circle horizontal gutter collects water from the roof and directs it to vertical gutters leading to the storage tank. The gutter system utilizes polyvinyl chloride (PVC) material, suitable for tropical climates with high rainfall. PVC gutters are readily available in the market at affordable prices. The gutter calculation involves determining the dimensions of the open channel gutter using Equation (11) and verifying it with Equation (10) as a control. Therefore, if Q in Equation (10) is less than or equal to Q in Equation (11), the design outcome meets expectations.

Table 6. Recapitulation of Analysis Results of Open Horizontal Gutter Dimensions

Slope (%)	**Q (m^3/s)**	***Yn* (m)**	**A (m^2)**	**P (m)**	**Rh (m)**	**V (m/s)**	**Qs (m^3/s)**
1	0,063	0,2	0,063	0,126	0,1	1,958	0,123

Based on Table 6, the dimensions of the gutter according to SNI 03-7065-2005 are 8 inches (0.063 m2) or 250 mm, with a water velocity flowing in the gutter of 1.958 m/sec and a water discharge flowing in the gutter of 0.123 ^{m3}/sec. Subsequently, the dimensions of both the vertical and horizontal gutters are calculated, guided by the specifications outlined in SNI 03-7065-2005 for determining the dimensions of semicircular open horizontal gutters. The roof surface area determines the size of the vertical gutter. The larger the roof surface area, the larger the pipe size, as it must accommodate a more significant load of rainwater.

The analysis results show that a roof area of 960 m^2 is converted to 463 m^2, and the roof area by SNI 03-7065-2005 is 8 inches. The size of the horizontal ½ circle gutter obtained is 8 inches, while the vertical and horizontal gutters are 4 inches.

3.8.2. First Flush Diverter Planning

Rainwater should be flushed at the first rainfall runoff, with 20 liters flushed per 100 m2 of the catchment area. The first flush is also a valuable intervention to reduce the stormwater system's suspended and dissolved contamination load. Such a first-flush system relies on the initial rain to wash the roof before water is allowed to enter the catchment basin.

First, flushing can also prevent rainwater from entering/interfering with the cleaning of the groundwater tank. For this research, the first flush components used are valves that function as opening and closing rainwater flow and a rainwater discharge pipe 0.5 m from the ground.

3.8.3. Storage Tank Volume Planning

In rainwater harvesting, planning the volume of the storage tank is crucial to ensure adequate water supply for various uses. The reference calculation for calculating the storage tank volume is based on the main supply in the rainy season: January, March, April, May, April, October, November, and December, which tend to have high rainwater supply availability, as shown in Table 5.

Based on the supply volume calculation with the needs volume, the ideal tank volume is 135 m^3, where the length is 10 m, width is 9 m, and height is 1.5 m. The reservoir in the ICU building at Dr. Agoesdjam RGH is planned as a ground tank because of the limited land in the ICU building at Dr. Agoesdjam RGH Hospital.

4. Conclusion

This research emphasizes the critical role of rainwater harvesting (RWH) as a sustainable water supply solution for Dr. Agoesdjam RGH. Through the analysis of clean water demand for the ICU building at Dr. Agoesdjam RGH, it can be seen that amounts to 2.6 m^3/day, translating to an estimated monthly demand of 78 m^3/month based on the number of beds (10) and employees (12) using standard guidelines for hospital plumbing system planning (SNI-03-7065-2005). This calculation underscores the critical need for adequate water supply management to meet healthcare facility requirements, emphasizing the importance of sustainable water resource planning and rainwater harvesting initiatives to supplement traditional water sources and enhance resilience against water supply challenges.

The analysis also shows that the rainfall intensity calculated for the hospital ICU building is 120 mm/hour, exceeding the threshold determined by SNI standards. This finding requires special design considerations for the roof area as a rainwater catcher to accommodate higher rainfall intensity and ensure effective rainwater capture. Through the analysis conducted, it was found that the roof area based on the SNI 03-7065-2005 standard needs to be adjusted from 960 m^2 to 463 m^2. This adjustment is significant in accurately determining the rainwater catchment area and optimizing the efficiency of the RWH system.

The specific dimensions for the gutter system are determined based on the SNI standard (03-7065-2005); from the analysis results, the horizontal ½ circle gutter size is identified as 8 inches, and the vertical and horizontal gutters are 4 inches. These dimensions ensure efficient water flow and collection in RWH systems. The analysis determined the required tank volume of 135 m^3, which was designed as a ground tank due to space constraints within the ICU building area. This volume calculation is crucial for ensuring adequate water storage capacity to meet hospital demands during periods of high rainfall.

5. Acknowledgment

First and foremost, I express my gratitude to my parents for their unwavering prayers and encouragement throughout my academic journey. I am also deeply thankful to Mr. Dr. Ir. Winardi ST, MT, and Ir. Danang Gunarto, ST, MT IPM, for generously sharing their valuable knowledge and providing insightful advice during the completion of this final project. Additionally, I appreciate my friends whose continuous support and assistance fueled my enthusiasm to conclude this final project. Special thanks are also to the Jurnal Teknik Sipil UNTAN (JTS) team for their willingness to publish the outcomes of my research. I hope this study's findings will benefit many individuals, particularly in advancing the understanding of rainwater harvesting using gutter and ground tank systems.

6. Author's Note

The author now declares that this article is an original work that does not plagiarize from any research and has passed the examination to obtain a bachelor of engineering degree at the Department of Environmental Engineering, Faculty of Engineering, Tanjungpura University.

7. References

Campisano, A., Butler, D., Ward, S., Burns, M. J., Friedler, E., DeBusk, K., ... & Han, M. (2017). **Urban rainwater harvesting systems: Research, implementation and future perspectives**. Water Research, 115, 195-209.

Chikabvumbwa, S., Suribabu, C. R., & Worku, D. (2019). **Rainfall Frequency Analysis using Gumbel Distribution**. IJCIRAS, 1 (1),

Da Silva, C. V. F., Schardong, A., Garcia, J. I. B., & Oliveira, C. D. P. M. (2018). **Climate Change Impacts and Flood Control Measures for Highly Developed Urban Watersheds**. Water, 10(7), 829.

Dentry, D., Utomo, K. P., & Sutrisno, H. (2023). **Perencanaan Sistem Penyediaan Air Bersih Di Terminal Antar Lintas Batas Negara (ALBN) Sungai Ambawang, Kabupaten Kubu Raya**. Rekayasa Hijau: Jurnal Teknologi Ramah Lingkungan, 7(1), 20-36.

de Sá Silva, A. C. R., Bimbato, A. M., Balestieri, J. A. P., & Vilanova, M. R. N. (2022). **Exploring Environmental, Economic and Social Aspects of Rainwater Harvesting Systems: A review**. Sustainable Cities and Society, 76, 103475.

Fadillah, M., Irsan, R., & Jati, D. R. (2023). **Studi Kandungan Asam Pada Air Hujan di Kota Pontianak**. Ecolab, 17(1), 25-32.

Gerber, N., Tschümperlin, C., & Hofer, S. (2017). **PromoS-Process Model for Non-Medical Support Services in Hospitals**.

Hidayati, N., Soeryamassoeka, S. B., & Herawati, H. (2023). **Rainfall Analysis for Creating Intensity-Duration-Frequency (IDF) Curve of Pontianak City**. Jurnal Teknik Sipil, 23(4), 10-18.

Jarwinda, J. (2021). **Analisis Curah Hujan Rencana Dengan Menggunakan Distribusi Gumbel Untuk Wilayah Kabupaten Lampung Selatan**. Journal of Science, Technology, and Visual Culture, 1(1), 51-54.

Mukaromah, H. (2020). **Rainwater Harvesting as an Alternative Water Source in Semarang, Indonesia: The Problems and Benefits Rainwater Harvesting as an Alternative Water Source in Semarang, Indonesia: The Problems and Benefits**. ICoPS Earth Environ. Sci, 447, 1-11.

PERMENKES No. 32 of 2017, **Standard standard quality healthl environment for water media for needs hygiene sanitation.**

Pokhrel, S. R., Chhipi-Shrestha, G., Hewage, K., & Sadiq, R. (2022). **Sustainable, Resilient, and Reliable Urban Water Systems: Making the Case for a “One Water” Approach**. Environmental Reviews, 30(1), 10-29.

Pratama, A., Yulianto, E., Gunarto, D., & Soeryamassoeka, S. B. (2022). **Analysis Of Water Distribution Services By Perumdam Tirta Khatulistiwa In Pontianak Barat Sub-District Using Epanet**. Jurnal Teknik Sipil, 22(2), 113-121.

Raimondi, A., Quinn, R., Abhijith, G. R., Becciu, G., & Ostfeld, A. (2023). **Rainwater Harvesting and Treatment: State of the Art and Perspectives**. Water, 15(8), 1518.

Ruhiat, D. (2022). **Implementasi Distribusi Peluang Gumbel untuk Analisis Data Curah Hujan Rencana**. Teorema: Teori dan Riset Matematika, 7(1), 213-224.

Sample, D. J., & Liu, J. (2014). **Optimizing Rainwater Harvesting Systems for the Dual Purposes of Water Supply and Runoff Capture**. Journal of Cleaner Production, 75, 174-194.

Sen, Z. (2020). **Water Structures and Climate Change Impact: A Review**. Water Resources Management, 34(13), 4197-4216.

Soerryamassoeka, S. B., Triweko, R. W., Yudianto, D., & Tini, K. (2018, September). **Challenges of Integrated Water Resources Management in Kapuas River basin**. In Proceedings of the 21st IAHR-APD Congress (Vol. 2, pp. 867-872).

Sudarmadji. (2014). **Pengelolaan Sumber Daya Air Terpadu**. Yogyakarta: Gadjah Mada University Press.

Suwarno, D., Kristianto, I. E., Triantoputro, B. A., & Santosa, B. (2021, October). **Kajian Pemanfaatan Air Hujan sebagai Air Bersih Industri di Kota Semarang**. In Prosiding Seminar Nasional Riset dan Teknologi Terapan (Ritektra) (pp. B4-B4).

Theron, M., Botma, Y., & Heyns, T. (2022). **Infection Prevention and Control Practices of Non-Medical Individuals in a Neonatal Intensive Care Unit: A Donabedian Approach**. Midwifery, 112, 103393.

Wuysang, J. E., & Soeryamassoeka, S. B. (2021). **A Study on Developing Theoretical Framework, Dimensions, and Indicators of Urban Water Security in Indonesia. In Water Security in Asia: Opportunities and Challenges in the Context of Climate Change (pp. 123-134)**. Cham: Springer International Publishing.